TRANSACTIONS ON ELECTROMAGNETIC SPECTRUM

The Novel Antipodal Vivaldi Antenna with Improved Gain

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Abstract: Antennas, which are positioned in environments where all sorts of wireless communication exist, are a fundamental building component of today's communication systems. There are several varieties of antenna structures, each of which operates in a particular frequency spectrum. One of these is the Vivaldi antenna structure, which is commonly used in ultra-wideband systems (UWB). The Vivaldi antenna's exceptional qualities make it ideal for broadband applications. Vivaldi antenna designs have evolved throughout time. The novel antipodal Vivaldi antenna is presented. The designed antenna has a compact size which is $40 \times 40 \times 1.6$ mm^3. The antenna employs FR4 dielectric material, characterized by a dielectric constant of 4.4 and a tangent loss value of 0.02. The sin-wave edge is applied to the conventional antipodal antenna to increase the gain of the antenna. The results show that the proposed antenna has a higher gain value than the conventional antipodal antenna, with a value of nearly 0.8 dBi. The suggested innovative antenna is applicable in diverse UWB applications.

Keywords: UWB, Vivaldi Antenna, Wideband, Gain enhancement.

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1. INTRODUCTION

Antennas used in ultra-wideband systems should have qualities such as appropriate impedance matching, compact size, cheap cost, and symmetrical and steady radiation patterns [1]. UWB antennas with these qualities do not allow the use of multiple narrowband antennas at the same time. Ultra-wideband antennas are employed in numerous applications such as microwave imaging, radar, communication systems, and remote sensing [2-9]. The fundamental reason is that these applications require high gain capabilities in addition to wideband operation.

Vivaldi antennas, created by Gibson in 1979, are one of the best options for the UWB field due to their simple designs, outstanding broadband performance, high gain, and low profile [10]. The Antipodal Vivaldi antenna (AVA), designed by Gazit in 1988, is an important improvement targeted at increasing the performance of the current construction. AVA offers several advantages, including small size, increased beam width, excellent efficiency, a higher front-to-back ratio, and a steady radiation pattern. Based on the literary work, many efforts have been implemented to improve the functionality of the AVA. Employing the substrate-integrated waveguides, dielectric lenses, Vivaldi arrays, parasitic patches, and metamaterials can given as the major examples.

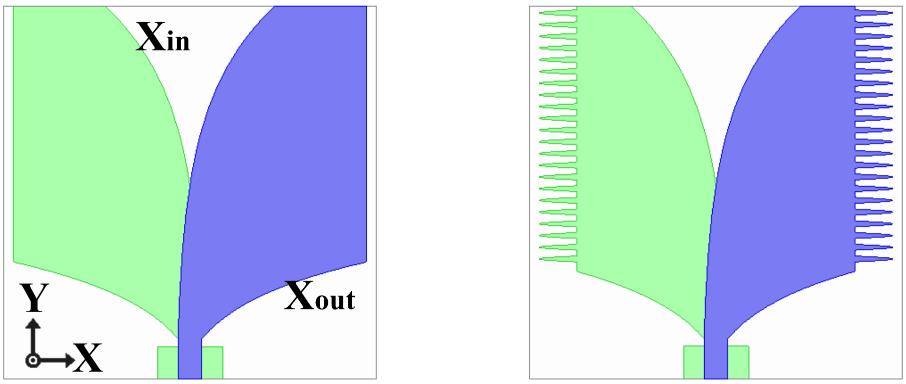
Some noteworthy studies are listed here. In 2011, Hood and Karaçolak introduced a small AVA design for UWB applications [11]. Bai et al. demonstrated a circular-shaped, gap-loaded AVA antenna [12]. Fei et al. used edges with a conical space to enhance radiation characteristics of downsized AVA [13]. Teni et al. achieved an AVA design with a compact dimension with improved radiation characteristics owing to the lens and extra slots [14]. Nassar and Weller added an additional circular patch to the flare aperture in order to upgrade the directivity and improve antenna performance in the AVA antenna they designed [15]. A fern-shaped AVA was presented by de Oliveira et al. [16]. In this paper, a novel AVA antenna, which is loaded with the sin-wave edge, is presented for increasing the antenna gain. In the next section, the designed antenna is explained in detail, and the results are provided, then the conclusion section that finishes the research.

2. DESIGN OF THE PROPOSED ANTIPODAL VIVALDI ANTENNA

Figure 1 shows the overall construction of the conventional and proposed Antipodal Vivaldi antenna. The substrate material for the antennas are FR4, which has a dielectric constant of 4.4 and a tangent loss of 0.02. the volume of the substrate is $40 \times 40 \times 1.6\ mm^3$. Eqs. (1-2) are used to calculate the antenna radiation elements [11].

$$x_{in} = \pm a_1 * \exp(b_1 * (y - w_h)) \pm a_1 \pm 0.5 * w_f \quad (1)$$

$$x_{out} = \pm a_2 * \exp(b_2 * (y - w_h)) \pm a_2 \pm 0.5 * w_f \quad (2)$$



(a) Conventional (b) Proposed

Figure 1. Antipodal Vivaldi Antennas

In these formulas, the parameter a_1 specifies the spacing among the antenna radiators next to the highest point of the AVA antenna. a_2 value determines the edge lengths of the antenna radiating elements in the upward side. b_1 and b_2 are the exponential growth factors of the lines which are generating the radiators. w_f and w_h represent the dimension of the antenna feeding. w_x and w_y represent the ground plane's dimensions in the cartesian coordinate system. Table 1 lists antenna's parameter values.

Table 1. The settings of antenna

Parameter	Value (mm)
Ws	40
Ls	40
h	1.6
a_1	0.3
a_2	0.3
b_1	0.1
b_2	0.1
w_h	4.27
w_f	2.5
w_x	7
w_y	3.5

All the parameters of the antennas are the same. However, the relationship among the proposed antenna and the classical AVA is the addition of sinus-shaped stubs on the vertical sides of the conventional AVA antenna. The amplitude and frequency values of the sin(x) are 4 mm and 5 Hz, respectively. The S-parameters of the conventional AVA and proposed AVA antenna are given in Fig. 2. When the graph is analyzed, it is observed that S(1,1) values are not very different in terms of minimum and minimum operating frequencies. The conventional AVA antenna has a minimum resonating frequency of 2.56 GHz, however, the proposed AVA antenna has a minimum resonating frequency of 2.60 GHz. The upper frequencies of the conventional AVA and proposed AVA are 11.4 and 11.2 GHz, respectively.

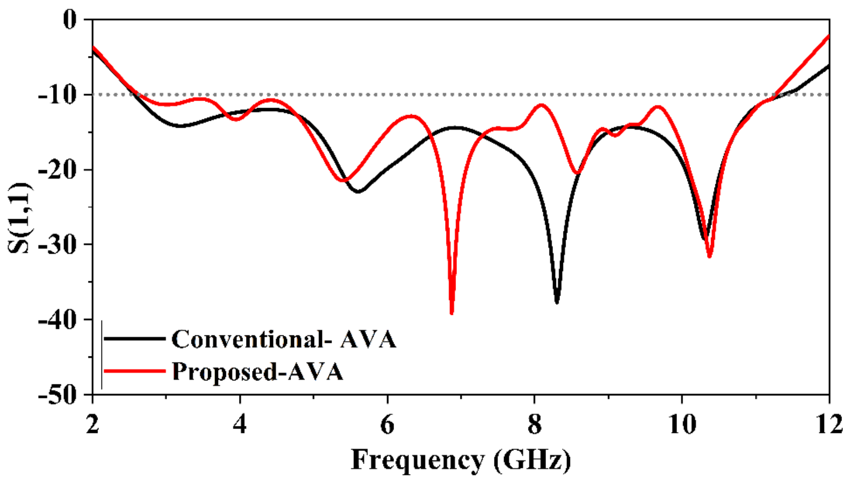
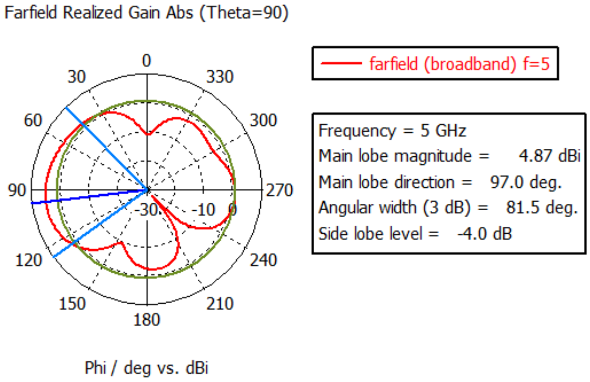
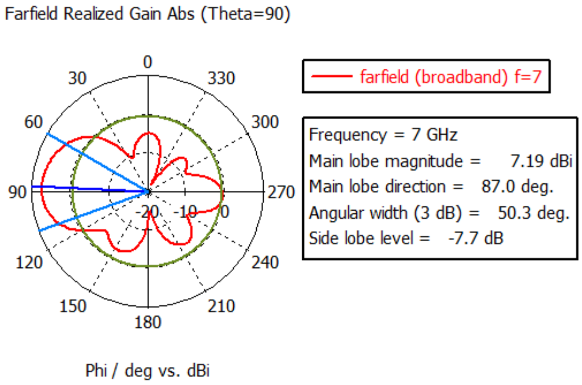


Figure 2. S(1,1) Graph of the designed AVA

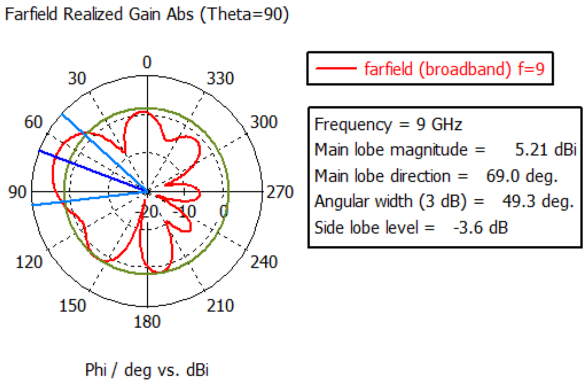
Figure 3 depicts the antenna's radiation patterns at different frequencies. According to the graphs, it is a reality that the antenna has directive radiation patterns at all frequencies.



(a) 5 GHz



(b) 7 GHz



(c) 9 GHz

Figure 3. Radiation patterns of the designed AVA at various frequencies

The gain graph of the antennas versus frequency is depicted in Figure 4. It is observed that the proposed antenna has a higher gain value than the conventional AVA antenna. The proposed one has a maximum value of 7.2 dBi; however, the conventional one has a maximum value of 6.4 dBi. This demonstrates that the suggested antenna outperforms the traditional AVA antenna.

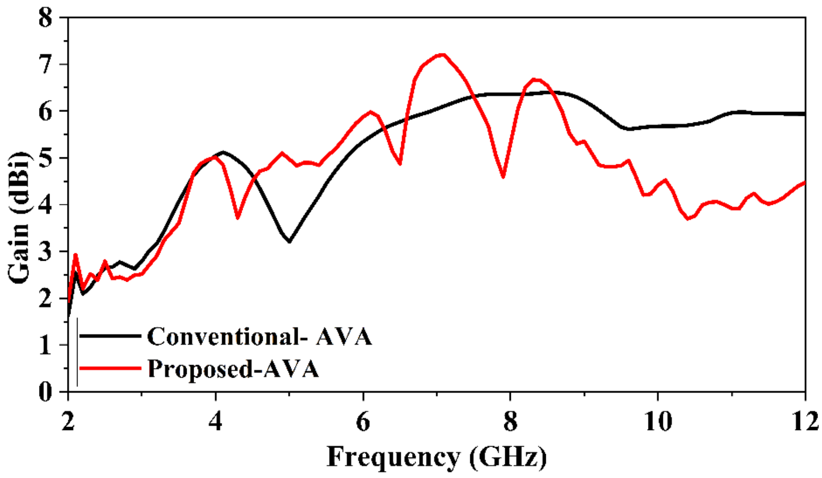


Figure 4. The gain graph of the AVA antennas versus frequency

Table 2 shows a comparison between the proposed antenna and comparable ones in the literature. In terms of size, the proposed antenna is one of the smallest antennas on the list with 40 × 40 × 40 × 1.6 mm³. This is particularly advantageous for compact communication systems. The proposed antenna has a bandwidth of 2.6 – 11.2 GHz, which covers the UWB band. However, Refs. [17] and [18] provide wider bandwidths such as 1.5 – 55 GHz and 2.7 – 18 GHz. The proposed antenna has a peak gain of 7.2 dBi, but it underperforms higher-gain antennas such as Refs. [17] (17.52 dBi) and [18] (13.45 dBi). In terms of gain, it is similar to Ref. [19] (6.7 dBi).

Table 2. Evaluation table of the intended antenna

Ref.	Substrate, Dielectric Constant	Dimension (mm^3)	Bandwidth (GHz)	Peak Gain (dBi)
Proposed	FR4 – 4.4	40 × 40 ×1.6	2.6 – 11.2	7.2
[17]	RO4003C – 3.38	95 × 175 × 0.51	1.5 – 55	17.52
[20]	Rogers-RT5880 – 2.2	80 × 40 × 0.508	6 – 18	13.45
[18]	FR4 – 4.6	94.14 × 73.2 × 1.6	2.7 – 18	10.527
[19]	FR4 – 4.4	89 × 42 × 1.6	4.15– 9.46	6.7

3. CONCLUSIONS

In this communication, the novel sin-wave loaded AVA antenna is presented. The antenna has a compact design; in addition, the performance parameter of the antenna, such as gain, is higher than the conventional AVA. It has a 0.8 dBi higher gain value. As a result, this paper proves that the gain of the AVA antenna is increased with the sin-wave loaded edge. The proposed antenna can be used in different UWB applications.

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